A Clinical Lecture

ON

MAXIMAL AND MINIMAL BLOOD PRESSURES AND THEIR SIGNIFICANCE.

DELIVERED AT THE MEDICAL GRADUATES' COLLEGE AND POLYCLINIC,

BY J. F. HALLS DALLY, M.A., M.D.CANTAB., M.R.C.P.LOND.,

ASSISTANT PHYSICIAN TO THE NATIONAL HOSPITAL FOR DISEASES OF THE HEART AND TO THE MOUNT VERNON HOSPITAL FOR CONSUMPTION; PHYSICIAN TO THE ST. MARYLEBONE GENERAL DISPENSARY.

WITHIN recent years and in many countries considerable interest has been taken in blood pressure. Much has been written and many sphygmomanometric instruments have been devised. For general purposes, these instruments, as I have shown in a previous paper,[1] may be grouped into two divisions, according to the main principles of their construction, the first division comprising those forms of apparatus founded upon the method of estimation of the pulse wave below the level of compression, whilst the second includes those based upon estimation of movements or oscillations of the arterial wall at the level of the compressed portion of the limb. As an example of the first group I will take an instrument of the Riva-Rocci type; as an example of the second group, the sphygmo-oscillometer of Pachon.

In any branch of experimental science not only is it advisable, but indeed essential, every now and again to call a halt in order that we may review our progress and position in the light of recent knowledge, while at the same time we assess and reassess as carefully as possible both the accuracy and extent of the groundwork upon which our superstructure rests. And it is for this very reason that I speak on this subject to-day, for, in my judgement, the greater part of the clinical work on arterial pressures hitherto attempted is founded on a basis, true so far as it goes, but which represents only a part of the whole truth.

First of all, what do people generally mean when they speak of blood pressure? In this country, when blood pressure is referred to, the radial systolic pressure registered by some or other modification of the Riva-Rocci sphygmomanometer is usually meant. Indeed, from the way in which many speak of "blood pressure," it would appear that a certain blood pressure is as characteristic of an individual as the colour of his hair or the shape of his nose. But this is not so, for although the blood pressure of a healthy individual may in general be confined within limits which possibly differ but little from those of his next-door neighbour, yet such pressure is not constant from month to month or from day to day, but from respiratory, psychical, or other causes may vary even during the time of investigation. In some subjects blood pressure is far more stable than in others, and observations over long intervals of time may approximate to an equal series, characteristic for each under like conditions. But this approximation is never absolute, for in reality blood pressure is a quantity capable of variation with each heart beat, with each change in tonus of vessel wall, with the peripheral resistance, and with the total volume of circulating blood. For an individual, in short, arterial pressure has no fixed value. It is always fluctuating and never isodynamic. Hence the maximal and minimal pressures between which arterial pressure normally varies are the important criteria which in every case we must definitely determine.

In a physiological laboratory the pressures within an opened artery form the usual subject of investigation, and, in any comparison between laboratory and clinical methods, it is necessary to bear in mind this fact, for the reason that, while such physiological methods usually record only the mean blood pressure, our clinical methods never measure the mean pressure, but either the maximum pressure (systolic), or the minimum pressure (diastolic), or both, according to the kind of instrument employed.

Those who are accustomed to work only with sphygmomanometers of the Riva-Rocci type urge that registration of the diastolic pressure is a needless refinement, and that for all practical purposes a record of the systolic pressure suffices. Further, it has even been stated that the "diastolic" pressure can have no true significance, since the pressure during diastole is continuously falling. In like manner, would it not be just as reasonable to ignore the "systolic" pressure, since during systole there is a rising pressure? In fact, such statement appears to show an entire lack of appreciation of the terms involved in practical sphygmometry, for, according to the accepted terminology, the pressure called "systolic" is that pressure which is recorded at the highest point of the systolic crest—in other words, the *maximal* pressure—while the "diastolic" is that pressure which is taken at the lowest point of the diastolic curve—in other words, the *minimal* pressure; and to intervening pressures, including the mean pressure, the terms "systolic" and "diastolic" are not without qualification applied. Pressures between the height of systole and the depth of diastole should properly be termed "interpressures," and although a knowledge of these is desirable, yet, at the same time, they should not be taken as criteria in blood pressure observations.

From the evidence which I now proceed to lay before you I think that you will agree that the above objections are mistaken ones, and that to record the maximum pressure whilst despising the minimum not only affords no indication of what the mean pressure is likely to be, but resembles attempting to solve a complicated problem of which one factor only is given. "No fact," says Janeway,[2] "regarding the blood pressure is better established than its wide range of variation in any individual. It is therefore impossible to speak of a normal value for blood pressure, but only of certain normal upper and lower limits."

Once we have succeeded in establishing the truth of this proposition, self-evident indeed but till of late unrecognized, we are confronted with another point, equally clear and direct, the importance of which in this country is only now becoming recognized, namely, the diastolic pressure. Marey[3] was the first to demonstrate as the criterion of the true diastolic pressure the external pressure at which maximum amplitude of the arterial wall becomes manifest, and the truth of this great and fundamental observation has since been verified by numerous workers. At the Annual Meeting of the British Medical Association in 1911, in reference to the use of Pachon's oscillometer, I said, "Now that we are in a position to institute a comparison between the maximal and minimal pressures, it will probably be found that of the two the *diastolic* is the more important."[4] Additional experience during the past two years has served to confirm the belief that I then expressed. And why do I say this? Chiefly for the reason that the diastolic pressure is a charge which the arteries must constantly bear, and from which they cannot escape. There is no point below which the *minimal* pressure can fall. The diastolic pressure, therefore, is a constant charge, whilst the systolic pressure represents only an intermittent supercharge.

Now let us examine in greater detail what is meant by the kind of statement so frequently made that a given blood pressure is found to be, say, 120 mm. Hg. This is usually taken to indicate that a distensile bag with outer non-elastic cuff has been placed around the arm above the elbow, and that air has been pumped into the bag until the pressure within it has been raised to height sufficient to obliterate the pulse at the wrist. The pressure in the bag is given either by a mercurial or aneroid manometer, and, in the example just given, the observer assumes that the pulse becomes extinguished when the manometer reading is 120 mm. Hg.

What has actually been recorded is simply the fact that in a given individual at a particular moment a pressure of 120 mm. had to be applied around the arm in order to cause the pulse at the wrist to disappear. From other evidence, the nature of which I need not now enter upon, it is assumed that this pressure is equal to the systolic pressure in the radial artery. Were the arteries rigid tubes like gas or water pipes, and were the blood a stationary fluid whose pressure was not constantly fluctuating on account of the beat of the heart between a systolic maximum and a diastolic minimum, by the ordinary laws of hydrostatics the pressure would undoubtedly be the same at every point. But the blood has dynamic energy, it is in constant movement, and the arteries are not rigid tubes which serve merely as conduits, but being themselves extremely distensile and elastic tubes exert a powerful influence upon the blood flow. We all know that in the arteries the pressure is high and intermittent, while in the veins the pressure is low and continuous. The intermittent flow in the arteries when passing through the capillaries is broken down into a continuous flow in the veins. Where does this breaking down occur? Are we to assume that the systolic pressure is the same from the aorta through the brachial into the radial artery, and that it is not until the blood stream arrives at the capillary area or just before the capillary area that the intermittent pressure is broken down into a continuous one in the veins? Or, alternatively, is the pressure being continuously broken down by the arteries throughout the whole of the course from aorta to capillaries? If the latter be the true explanation, the systolic pressure should be higher in the aorta than in the brachial, higher in the brachial than in the radial, and so on. Accordingly we should speak, not of *the* systolic pressure, but of the brachial, radial, femoral, etc., systolic pressure, as the case may be. What really happens with the Riva-Rocci type of instrument is that the observer compresses one artery, the brachial in the arm, whilst he takes as the systolic pressure the disappearance (or return) of the pulse in another artery, the radial in the forearm. Quite apart from disadvantages due to personal differences in tactile sensibility, inertia of the mercury column, etc., the fact is that the compression is exercised, not at a point which coincides with that at which the pulse is felt to disappear (or return), but at a different level altogether, and I can easily show you that when the pulse has already disappeared in the radial artery the brachial artery still shows ample pulsations.

Leaving this point for a moment, from another aspect I wish to direct your attention to the inadequacy of considering the systolic reading alone. Supposing the interval between the top of the systolic crest of the pressure wave and the bottom of the diastolic notch were always the same, it would not matter which reading we took, and we might then safely rely on systolic pressures alone. As it is, however, merely to state this assumption is sufficient to show its falsity. We all know that the size of the pulse—the amplitude of the pulse curve—varies enormously in different individuals, and indeed in the same individual at different times. In other words, the relation between the systolic maximum and the diastolic minimum varies. Let me give you a supposititious illustration: In one man the systolic pressure in the radial artery is 140 and the diastolic pressure is 80; in another the systolic is 120 and the diastolic is 100. Which of the two has the higher blood pressure? In which is the artery undergoing the greater strain? If we are content to record systolic pressures alone, unquestionably we should say that the man with a systolic pressure of 140 ran the graver risk. If we regard the diastolic alone, we should say that the artery of the second individual was exposed to the greater strain, but if we take the arithmetical mean, assuming for the sake of argument that the mean figure between the two extremes represents the mean pressure, we see that the strain is equal in the two cases. Now, as a result of investigations extending over some considerable time, I have found in many cases, and especially in aortic regurgitation which affords some of the best and most striking examples, that an abnormally high systolic pressure is accompanied by an abnormally low diastolic pressure. Hence to record systolic pressures alone is fallacious and misleading.

Let me give you as illustrations two actual cases:

A certain patient of mine suffering from aortic regurgitation gave as his systolic pressure 210 mm. Hg. Another man—a case of granular kidney—gave a systolic pressure of 180. Had I regarded the systolic pressures alone I should have said that the aortic case had the higher blood pressure, and that his arteries were in a condition of greater stress than those of the man with granular kidney. But a record of the diastolic pressure in each case put an entirely different construction on the matter. The diastolic pressure of the aortic case was 70 mm. Hg, whilst that of the renal case was 140—that is to say, the renal case had his arteries constantly kept on the stretch by a minimal pressure of 140, which during systole rose to 180; whilst in the aortic case the diastolic pressure was only half this amount, and it was solely during the brief interval of time represented by the upper part of the sharp systolic peak that the pressure reached a notable elevation. During diastole the arteries were far less stretched than normal. Various other considerations have convinced me of the futility of taking only the systolic pressure, which I do not propose to enter into here, as I think enough has been said to show that any argument based upon systolic readings alone must be received with the very greatest caution.

If under pathological conditions the interval between the systolic maximum and the diastolic minimum can vary to degrees even more extreme than shown by the cases I have just cited, the question naturally arises, May there not be from time to time physiological variations in the same individual? Is it not possible, for instance, that the systolic pressure may rise and the diastolic fall, so that while the mean pressure remains constant, either a systolic or diastolic reading, if considered separately, would show a variation in pressure? What I regard as an extremely important contribution to our knowledge of the subject has recently been made in a paper read before the Royal Society by Dr. Russell Wells and Professor Leonard Hill[5] on the influence of the resilience of the arterial wall on blood pressure and on the pulse curve. It is possible that I am attaching more importance to this than it deserves, since I am partly responsible for the work on which it is based, and shall shortly, in conjunction with others, publish this evidence in full, so that it can be criticized and confirmed or refuted. Nevertheless, as I personally believe it to be true, I feel it only right in discussing this subject to give you the outlines of the view in question.

Up to the present time it has been assumed that arterial elasticity is a fixed quantity for each artery, and does not vary. The suggestion is now made that the arteries have the power of becoming more or less rigid, less or more resilient from time to time under the influence of the nervous system, or from other causes. In order to be clear, perhaps it would be well to explain my meaning at greater length, and if I seem to some of you to be talking rather elementary physiology, I trust that you will forgive me, as I find it rather difficult adequately to explain this idea without some simple illustrations. The word "resilience" is used to express the ease with which an elastic tube distends with a rise and recoils with a fall in pressure of the contained fluid. In this sense a glass tube possesses no resilience. A rubber tube with a wall 0.2 mm. thick is more resilient than one with a wall 0.4 mm. thick. The thinner, more resilient tube yields with a rise and recoils with a fall of pressure to a greater extent than does the harder and thicker-walled one. If the arteries were rigid tubes, and if the systolic pressure generated at each beat of the heart were, say, 140 mm. Hg in the aorta and the diastolic 60, both systolic and diastolic pressures would be constant throughout the arterial system and at the threshold of the capillary area. But the arteries are not rigid tubes; they are resilient, and consequently their walls become distended during systole and recoil during diastole. Hence, further down the arterial tree we shall find the systolic pressure lowered, say, to 130 mm. Hg, and the diastolic raised, say, to 70. Were the resilience of the different arteries a fixed quantity for each, the amount by which the systolic pressure would have fallen and to which the diastolic would have been raised would be always the same for the same pressure differences at the heart. But the vasomotor tonus is constantly changing in various portions of the arterial system so as to meet the local requirements, and if for any reason a particular artery becomes more resilient, the systolic pressure within that artery will be further reduced and the diastolic more raised.

Even this assumption, however, is not unchallenged, for Russell[6] of Edinburgh declares that some of the pressure in the sphygmomanometer bag is used up in overcoming the resistance of the vessel wall. According to him, therefore, the systolic pressure in the radial artery in our example would be 120 minus x mm., x being the amount required to cause the vessel wall to collapse. Others, again, have maintained that x is a negligible quantity, and that 120 would really represent the radial systolic pressure. I am not at present concerned in discussing this point or the other assumptions that underlie the statement that the method I have outlined gives the true systolic pressure in the radial artery. I do, however, wish to point out that all that can be asserted is that the systolic pressure was 120 mm. in the artery observed at the moment of observation.

From the fact that in healthy young adults in the recumbent posture the systolic pressure in the posterior tibial artery is found to be about the same as in the radial when similarly measured, there seems to have arisen a supposition, tacit perhaps rather than avowed, that the systolic pressure in all the arteries of the body would be much the same. This is a very large supposition, and, as I believe, an erroneous one.

Having already demonstrated that a record of systolic pressure is of slight value in the absence of a simultaneous record of diastolic pressure, we next have to ask, What are the instruments which afford the information that we seek? Instruments recording both pressures are few in number, and of these the best are the sphygmomanometer of Erlanger and the sphygmo-oscillometer of Pachon. For graphic records of physiological blood pressure in suitable cases Erlanger's apparatus has considerable utility. In clinical medicine, nevertheless, its employment is contra-indicated, since it is too complicated, cumbersome, and expensive for purposes other than those of the laboratory.

No such objections apply to Pachon's sphygmo-oscillometer, which is less expensive, easily portable, and simple in application. Moreover, if properly used, it eliminates the personal equation, so that, having now used this instrument for upwards of three years, and having tested it against a large number of other apparatus, I am able to say that with it I have obtained very useful clinical results. By this I do not mean to say that I consider it a perfect instrument, but it is certainly quite a good one, and both in private work and in hospital I use it in preference to any other. One minute only is required for an observation, which, however, I always repeat for the sake of accuracy, and at the end of this short time one has a complete record of maximal pressure, minimal pressure, and amplitude of pulse wave.

In stating that the Pachon sphygmo-oscillometer gives a record of maximal and minimal pressures, I do not say that even these figures represent the real blood pressures of the case under observation. More investigation on this point is required than I have yet been able to make. The salient fact is that both pressures are obtained simultaneously by the use of the *same* method, and that these are relative one to the other, thus affording exceedingly valuable clinical comparisons over large numbers of cases. It is of no avail to measure one pressure by a mercurial manometer, for example, and another by the method of oscillations, for readings of the systolic pressure by one method and of the diastolic by another method totally different in principle fail to give results which are sufficiently accurate to be comparable with advantage. In fine, my opinion is that an absolutely satisfactory means of recording at the bedside the various blood pressure data has yet to be discovered.

To a future occasion I must leave the remarks which I had hoped to make on readings taken in the manner I have described as guides to prognosis and treatment. It has been denied that blood pressure records can give any useful indications in these respects; but, again, this pronouncement has been made from consideration of systolic apart from diastolic pressures. Personally, I may say that I often find readings taken at frequent intervals of considerable assistance when considered in conjunction with the other available physical signs and symptoms. For instance, if in a case of arterio-sclerosis both pressures are rising in spite of treatment, the import of this is unfavourable. In a patient of mine, a lady aged 65, the subject of hypertrophy of the left ventricle, generalized arterio-sclerosis, and some chronic interstitial nephritis, the arterial blood pressures, systolic and diastolic, have been throughout the past two years very high. Some nine months ago the pressures rose, and I considered her to be in danger of cerebral apoplexy. This event speedily happened, being associated with paresis of face, arm, and leg on the same side, from which now the patient has made very fair recovery, and the blood pressure has become slightly lower than the original figures. As regards treatment, the case of a schoolboy, aged 14, with well-marked double aortic disease, is of interest. On his first visit the readings were 20—2—8, the first being the systolic pressure in centimetres Hg, the last the diastolic, and the intermediate figure the amplitude of pulse wave. Three weeks later the readings were 14—0.5—7, the general condition and state of the circulatory system having correspondingly improved.

It would be easy to multiply examples of general diseases as well as of circulatory affections, but, since I hope to deal with these in a later paper, I will conclude with the recommendation that, as opportunities present themselves, you will test for yourselves the importance of registering diastolic as well as systolic pressures.

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THE IDIO-VENTRICULAR RHYTHM.

A CLINICAL CASE WITH POLYGRAPHIC RECORDS.

BY CHARLES ALLEN ROBINSON, B.A., M.B., B.C.CANTAB.,
LEOMINSTER, HEREFORDSHIRE.

THE term "bradycardia" is applied correctly to those cases of infrequent heart action in which the auricles participate in the infrequency. It may be either normal or of the so-called nodal type.

In the normal bradycardia the auricular contractions bear the normal time relationship to those of the ventricular. The term "nodal bradycardia" is applied to that form in which the auricular contractions occur simultaneously with, or very slightly before or after the ventricular contractions. The case on which this paper is based may be regarded as one primarily of bradycardia, and it has some features in common with nodal bradycardia as defined. It differs, however, in this, that the polygraphic records show a regularly-recurring auricular contraction to which the ventricle fails to respond.

In cases in which the conduction of impulses is not interfered with, the idio-ventricular rhythm asserts itself, provided the period of time occupied by the rhythmic formation of impulses is less in the ventricles than in the auricles. So that a lengthening of the time of stimulus formation at the sinus, or a lessening of the time in the ventricles, or a combination of these, will produce the assumption of the idio-ventricular rhythm.

In the case of bradycardia we have, then, an essential element for the production of the idio-ventricular rhythm, provided the bradycardia is sufficiently pronounced, and the period of time occupied by stimulus formation in the ventricle is not also lengthened sufficiently to prevent the ventricular rhythm from coming into action.

A Case Illustrating Idio-ventricular Rhythm.

On December 5th, 1912, a patient came to me complaining that he was unable to continue his work because of pains in the chest, arms, and legs, and some breathlessness. He is a blacksmith by trade, aged 32 years. He has been at this trade for the last ten years, but previously to that from the age of 16 years had been employed in a coal mine. He is a small man and not of good muscular development.

There is no history of illness or injury likely to cause affection of the heart. He denies having had syphilis. He has had no attacks of fainting.

He has a troublesome cough, with some expectoration.

The pulse is small and at the rate of 40 per minute, and is almost regular in rhythm. There is no evidence of atheroma. The heart sounds are clear but faint, and they correspond to the beats of the radial pulse.

The lungs are emphysematous, which prevents the size of the heart being determined. There are no signs in the lungs to account for the cough. There is some tenderness and increased muscular resistance in the region of the liver.

There is no oedema of the extremities or other signs of heart failure other than those mentioned.

The urine does not contain albumin.